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Patent

Case No.: 55271US002

JFW AF

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

First Named Inventor: GEISSINGER, JOHN D.

Application No.: 09/491302 Group Art Unit: 2815

Filed: January 25, 2000 Examiner: Paul E. Brock II

Title: ELECTRONIC PACKAGE WITH INTEGRATED CAPACITOR

**BRIEF ON APPEAL**

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*Melanie Gover*

Signed by: Melanie G. Gover

Dear Sir:

This is an appeal from the Office Action mailed on March 15, 2004. This Brief is being filed in triplicate. The fee required under 37 CFR § 1.17(c) for the appeal should be charged to Deposit Account No. 13-3723. Appellant requests the opportunity for a personal appearance before the Board of Appeals to argue the issues of this appeal. The fee for the personal appearance will be timely paid upon receipt of the Examiner's Answer.

**REAL PARTY IN INTEREST**

The real party in interest is 3M Company (formerly known as Minnesota Mining and Manufacturing Company) of St. Paul, Minnesota and its affiliate 3M Innovative Properties Company of St. Paul, Minnesota.

**RELATED APPEALS AND INTERFERENCES**

Appellants are unaware of any related appeals or interferences.

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**STATUS OF CLAIMS**

Claims 1 to 4 and 8 to 19 are pending. Claims 1 to 4 and 8 to 19 have been finally rejected. Claims 5 to 7 and 20 to 26 have been withdrawn from consideration.

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Claims 1 to 4 and 8 to 19 are pending. Claims 1 to 4 and 8 to 19 have been finally rejected. Claims 5 to 7 and 20 to 26 have been withdrawn from consideration.

Claims 1 to 4 and 8 to 16 stand rejected under 35 USC § 103(a) as being unpatentable over Kling (US 2002/0048972) in view of Brandt (U.S. 6,068,782).

Claims 17 to 19 stand rejected under 35 USC § 103(a) as being unpatentable over Kling (US 2002/0048972) and Brandt (U.S. 6,068,782) as applied to claim 1 and further in view of Fujisawa (U.S. 6,184,457).

**STATUS OF AMENDMENTS**

An Amendment to correct formalities in the Application is being filed concurrently with this Appeal Brief. A copy of the Amendment is included herewith.

**SUMMARY OF THE INVENTION**

The invention disclosed herein relates generally to electronic packages and more specifically to an electronic package with an integrated capacitor.

Claim 1 provides an electronic package, comprising: a conductive trace layer having a first side and a second side, the conductive trace layer being patterned to define a plurality of interconnect pads; a dielectric substrate mounted on the first side of the conductive trace layer; an embedded capacitor having a capacitance of from about 1 nF/sq.cm. to about 100 nF/sq.cm., including a first conductive layer, a second conductive layer and a layer of dielectric material made of a non-conductive polymer blended with high dielectric constant particles disposed between the first and the second conductive layers, the first conductive layer attached to the second side of the conductive trace layer by a first adhesive layer; a plurality of interconnect regions extending through the first conductive layer and the dielectric material layer of the capacitor; and an interconnect member connected between each of the conductive layers of the capacitor and a corresponding set of the interconnect pads, the first conductive layer of the capacitor being electrically connected to a first set of the interconnect pads and the second conductive layer of the capacitor being electrically connected to a second set of the interconnect pads, the interconnect members corresponding to the second set of interconnect pads extending

through one of the interconnect regions. This invention is described in the specification, among other places, at page 3, line 20 to p. 4, line 7 and p. 7, lines 6-9.

Claim 2, which depends from claim 1, provides an electronic package wherein the first electrode is maintained at a first reference voltage and wherein the second electrode is maintained at a second reference voltage different from the first reference voltage. This invention is described in the specification, among other places, at page 8, lines 17-18.

Claim 3, which depends from claim 1, provides an electronic package further comprising an electrically conductive stiffening member attached to the second conductive layer of the capacitor by a second adhesive layer. This invention is described in the specification, among other places, at page 7, lines 9-10.

Claim 4, which depends from claim 3, provides an electronic package further comprising a device receiving region extending through the dielectric substrate, the conductive trace layer and the capacitor, and further comprising an electronic device attached to the device receiving region on the stiffening member by a third adhesive layer. This invention is described in the specification, among other places, at page 4, lines 22-25 and page 7, lines 10-11.

Claim 8, which depends from claim 1, provides an electronic package wherein the capacitor has a capacitance of from about 2 nF/sq. cm. to about 30 nF/sq. cm. This invention is described in the specification, at page 3, in the paragraph beginning on line 17, as amended by the concurrently filed Amendment.

Claim 9, which depends from claim 1, provides an electronic package wherein the capacitor has a capacitance of from about 5 nF/sq. cm. to about 15 nF/sq. cm. This invention is described in the specification, at page 3, in the paragraph beginning on line 17, as amended by the concurrently filed Amendment.

Claim 10, which depends from claim 1, provides an electronic package wherein the capacitor has a capacitance of at least 30nF/sq. cm. This invention is described in the

specification, at page 3, in the paragraph beginning on line 17, as amended by the concurrently filed Amendment.

Claim 11, (as amended in the concurrently filed Amendment) which depends from claim 1, provides an electronic package wherein the dielectric material of the capacitor has a thickness of from about 0.5 um to about 30 um. This invention is described in the specification, among other places, at page 6, lines 9-12.

Claim 12, which depends from claim 1, provides an electronic package wherein the dielectric material of the capacitor includes a metal oxide. This invention is described in the specification, among other places, at page 3, lines 17-20.

Claim 13, which depends from claim 1, provides an electronic package wherein the dielectric constant particles are formed from a material selected from the group consisting of barium titanate, barium strontium titanate, titanium oxide, lead zirconium titanate and tantalum oxide. This invention is described in the specification, among other places, at page 3, lines 17-20.

Claim 14, which depends from claim 1, provides an electronic package wherein the dielectric substrate includes a plurality of apertures, each one of the apertures being positioned adjacent to one of the interconnect region of the capacitor. This invention is described in the specification, among other places, at page 4, lines 22-25.

Claim 15, which depends from claim 1, provides an electronic package wherein the dielectric substrate includes a polymeric film. This invention is described in the specification, among other places, at page 3, lines 23-25.

Claim 16, which depends from claim 1, provides an electronic package wherein said polymeric film is polyimide film. This invention is described in the specification, among other places, at page 3, lines 23-25.

Claim 17, which depends from claim 1, provides an electronic package wherein the interconnect member is a solder plug. This invention is described in the specification, among other places, at page 7, lines 26-28.

Claim 18, which depends from claim 1, provides an electronic package wherein each interconnect pad is a solderball pad. This invention is described in the specification, among other places, at page 7, lines 21-23.

Claim 19, which depends from claim 18, provides an electronic package wherein the dielectric substrate has an aperture extending therethrough adjacent to each solderball pad. This invention is described in the specification, among other places, at page 4, lines 22-25 and p. 7, lines 21-23.

#### ISSUES ON APPEAL

1. Whether claims 1 to 4 and 8 to 16 stand rejected under 35 USC § 103(a) as being unpatentable over Kling (US 2002/0048972) in view of Brandt (U.S. 6,068,782).
2. Whether claims 17 to 19 stand rejected under 35 USC § 103(a) as being unpatentable over Kling (US 2002/0048972) and Brandt (U.S. 6,068,782) as applied to claim 1 and further in view of Fujisawa (U.S. 6,184,457).

#### GROUPING OF CLAIMS

All of the claims stand or fall together. No admission, however, is being made with respect to the obviousness of the subject matter of the dependent claims with respect to the subject matter of the independent claims.

#### ARGUMENTS OF APPELLANTS

##### Background

Electronic packages facilitate the mounting and handling of electronic devices such as microprocessors, video controllers and memory. Capacitors are used to decouple the system-

level power supply from individual electrical devices of an electronic package. Decoupling of an electronic device from the power supply reduces the overall noise in the power distribution network of the electronic package. However, due to increases in the speed and electrical current associated with high-speed electronic devices, traditional capacitor structures do not provide adequate performance because the inductance associated with these types of capacitors inhibits their operation at high speeds. Interconnect inductance in an electronic package chokes the capacitor, preventing the high-speed transfer of electrical current to and from the capacitor.

Embedding capacitors directly into the electronic packages provides significant decoupling capacitance with very low interconnect inductance. Furthermore, the electrodes of the capacitor may serve as reference voltage planes in the electronic package for providing excellent power distribution within the package. This approach facilitates very high-speed operation of electronic devices within an electronic package.

**Issue 1:** Claims 1 to 4 and 8 to 16 are not unpatentable over Kling (US 2002/0048972) in view of Brandt (U.S. 6,068,782).

In rejecting claims 1 to 4 and 8 to 16 as being unpatentable over Kling (US 2002/0048972) in view of Brandt (U.S. 6,068,782), the Office Action states in part:

Claims 1 -4 and 8 -16 are rejected under 35 U.S.C. 103(a) as being unpatentable over Kling et al. (US 2002/0048927 A1, Kling) in view of Brandt et al. (USPAT 6068782, Brandt). With regard to claim 1, Kling discloses in figure 1 an electronic package. Kling discloses in figures 1-3b a conductive trace layer (Pads in figure 3b) having a first side and a second side, the conductive trace layer being patterned to define a plurality of interconnect pads. Kling discloses in figures 1-3b a dielectric substrate (16, see figure 1) mounted on the first side of the conductive trace layer. Kling discloses in figures 1 -3b and paragraph 18 an embedded capacitor (14 in figure 1) having a capacitance of 50 nF/sq.cm including a first conductive layer (Power plane, figure 3b), a second conductive layer (Digital ground plane, figure 3b) and a layer of dielectric material (labeled AlO<sub>2</sub> in figure 3b) made of a non-conductive polymer (polyimide) disposed between the first and the second conductive layers, the first conductive layer attached to the second side of the conductive trace layer by a first adhesive layer (labeled SiO<sub>2</sub> in figure 3b). Kling does not disclose that the dielectric material is made of a non-conductive polymer blended with high dielectric particles. Brandt discloses in column 4, lines 18 - 41 a suitable dielectric material made of a non-conductive polymer blended with high dielectric particles. It would have been obvious to one of ordinary skill in the art at the time of the present invention to use the dielectric material of Brandt in the method of Kling in order to tune the electronic properties of a capacitor component as stated by Brandt in column 4, lines 22 -41. Further, Kling teaches in paragraph 18 that any suitable dielectric material. Kling discloses in figures 3a and 3b a plurality of interconnect regions (one shown in figure 3b just to the right of the "AlO<sub>2</sub>" arrow) extending through the first conductive layer and the dielectric material layer of the capacitor. Kling discloses in figure 1 an interconnect member (in figure 3b shown as the dark line lining the interconnect regions) connected between each of the conductive layers of the capacitor and a corresponding set of the interconnect pads, the first conductive layer of the capacitor being electrically connected to a first set of the interconnect

pads and the second conductive layer on the capacitor being electrically connected to a second set of the interconnect pads, the interconnect members corresponding to the second set of interconnect pads extending through one of the interconnect regions.

Kling discloses embedded capacitor multi-chip modules. The Kling Abstract states that the invention provides systems and methods for interconnecting circuit devices, wherein decoupling capacitors are disposed on a substrate and an interconnect layer having a pattern of circuit connections is formed by a deposition process over the capacitors thereby embedding the decoupling capacitors within the interconnect layer.

Brandt discloses individual embedded capacitors for laminated printed circuit boards. Brandt is cited by the Examiner as teaching a non-conductive polymer blended with high dielectric particles.

Kling in combination with Brandt, however, do not disclose the invention as defined in claims 1 to 4 and 8 to 16 and, therefore, do not make the claims obvious. According to MPEP 2142, to establish a case of *prima facie* obviousness, three basic criteria must be met: 1) there must be some suggestion or motivation, either in the references or generally known to one skilled in the art, to modify or combine reference teachings, 2) there must be reasonable expectation of success, and 3) the prior art references must teach or suggest all the claim limitations. The ability to modify the method of the references is not sufficient. The reference(s) must provide a motivation or reason for making the changes. *Ex parte Chicago Rawhide Manufacturing Co.*, 226 USPQ 438 (PTO Bd. App. 1984).

Applicants respectfully submit that the Office Action misinterprets a number of aspects of the teachings of Kling:

A) The Office Action states that interconnect layer 16 in Fig. 1 of Kling is a dielectric substrate.

Applicants responded that it is clearly stated in Kling that interconnect layer 16 has at least one metal layer. (*See, e.g.*, Kling at p. 2, paragraph 27 and p. 5, paragraph 40.) Accordingly, Kling does not disclose a dielectric layer mounted on one side of a trace metal layer.

The Examiner responded as follows:

It should be noted that Kling discloses in paragraph 40 “interconnect layer 16 can be formed on top of the component layer. In one practice, and [sic] *in situ* process can be performed wherein a **dielectric** layer is directly deposited on the upper surface of the plurality of components, in this case the decoupling capacitors 14 and the resistive element 22. Further processing can include **patterning and forming vias in the *in situ* formed dielectric layer.**” [emphasis added] It can be seen from this quotation that interconnect layer 16 comprises at least one dielectric layer, and thus interconnect layer 16 can be considered a dielectric layer. There is no evidence on the record that suggests an interconnect layer comprising both dielectric layers and metal layers cannot be considered a dielectric layer.

Kling describes interconnect layer 16 as comprising a plurality of signal, power, and ground planes that provide a pattern of circuit connections for interconnecting circuit devices. (Kling at p. 2, paragraph 27) The interconnect layer has at least one metal layer. (Kling at p. 5, paragraph 40). Applicants maintain that Kling does not disclose a dielectric layer mounted on one side of a trace metal layer. The Examiner’s position that an interconnect layer comprising both dielectric layers and metal layers can be considered a dielectric layer makes it impossible to distinguish between a dielectric layer containing no metal layers and a dielectric layer containing metal layers.

B) The Office Action states that the SiO<sub>2</sub> (silicon oxide) layer in Fig. 3b is an adhesive.

Applicants responded that it is known in the art that SiO<sub>2</sub> is not an adhesive.

The Examiner responded as follows:

First, it should be noted that applicant does not provide any evidence that “it is known in the art that SiO<sub>2</sub> is not an adhesive.” Nothing on the record suggests that SiO<sub>2</sub> is not an adhesive. Second, it should be noted that “SiO<sub>2</sub>” is only referred to as a label “a first adhesive layer (labeled SiO<sub>2</sub> in figure 3b).” Paragraph 18 explicitly gives examples of other materials that are well-known adhesives (i.e. polyimide). In this case, a label layered SiO<sub>2</sub> is attaching the first conductive layer to the second side of the conductive trace layer.

Because it is known in the art that silicon oxide is not an adhesive, Applicants did not believe it was necessary to provide additional evidence to that effect. However, Applicants have

attached hereto as **Exhibit A**, two dictionary definitions of silicon dioxide, which clarify that it is not an adhesive.

In regard to the Examiner's comment that SiO<sub>2</sub> is only a label and that paragraph 18 explicitly gives examples of other materials that are adhesives, Applicants point out that the list of materials in paragraph 18 are dielectric materials suitable for the dielectric layer of the capacitor, not adhesive materials that may be used to adhere a conductive layer of the capacitor to a conductive trace layer. Paragraph 18 specifically states that “[t]he decoupling capacitors can comprise a silicon oxide dielectric, a polyimide dielectric, aluminum oxide, organic material dielectrics, or any other suitable dielectric material”.

Further, although some polyimides are adhesives, the polyimide listed in Kling is a dielectric polyimide and it is its dielectric, not adhesive, property that is relevant.

Additionally, Kling explicitly states that Fig. 3b is a cross-sectional view of decoupling capacitors 36 and 44 [which are depicted in Fig 3a]. (Kling p. 4, paragraph 35) It identifies silicon base 48, ground plane 50, power plane 52, and dielectric material disposed between, which can be any suitable dielectric material such as SiO<sub>2</sub>, polyimide or any other suitable material. It goes on to state that the power planes, ground planes and dielectric material can be stacked in layers to provide a selected capacitance appropriate for the application. It further states that gaps 54 can be disposed within the power or ground planes (emphasis added) to allow for separating the power and ground planes from each other and that the metal layers within the interconnect layer 16 can electrically couple to these pads [which are adjacent the gaps], thereby connecting the circuit pattern to the power and ground planes.

As the foregoing indicates, and as is apparent from Fig 3a, the layer identified as SiO<sub>2</sub> and the pads are part of the capacitors. They are not an adhesive layer and trace layer, respectively, as the Examiner asserts in the office action.

Based on the foregoing, Applicants respectfully submit that the references cannot support a case of *prima facie* obviousness as to the claims because, among other possible reasons, the cited references do not disclose all the elements of the present invention. In particular, the references do not disclose a conductive layer of a capacitor attached to a trace layer with an adhesive. Accordingly, the rejection is improper and should be withdrawn.

**Issue 2: Claims 17 to 19 are not unpatentable over Kling (US 2002/0048972) and Brandt (U.S. 6,068,782) as applied to claim 1 and further in view of Fujisawa (U.S. 6,184,457).**

In rejecting claims 17 to 19 stand rejected under 35 USC § 103(a) as being unpatentable over Kling (US 2002/0048972) and Brandt (U.S. 6,068,782) as applied to claim 1 and further in view of Fujisawa (U.S. 6,184,457), the Office Action states in part:

With regard to claim 17, Kling discloses in figures 1-3 an interconnect member. Kling does not teach that the interconnect member is a solder plug. Fujisawa discloses in figure 1 wherein the interconnect member is a solder plug. It would have been obvious to one of ordinary skill in the art at the time of the present invention to use the solder plug of Fujisawa in the device of Kling and Brandt in order to electrically fill the interconnect with a material which is widely available and understood in the art.

With regard to claim 18, Kling discloses in figure 1 wherein an interconnect pad. Kling does not teach wherein each interconnect pad is a solder pad. Fujisawa teaches in figure 8 interconnect pad (28 and 32) is a solder pad. It would have been obvious to one of ordinary skill in the art at the time of the present invention to use the solder pad of Fujisawa as the interconnect pad in the device of Kling and Brandt in order to use pad material which is widely available and understood in the art.

The combination of Kling and Brandt and further in view of Fujisawa do not disclose the invention as defined in claims 17 to 19 and, therefore, do not make the claims obvious.

Applicants respectfully submit that, for the same reasons given in the section above addressing the rejection of claims 1 to 4 and 8 to 16, the references cannot support a case of *prima facie* obviousness as to claims 17 to 19 because, among other possible reasons, the cited references do not disclose all the elements of the present invention. Accordingly, the rejection is improper and should be withdrawn.

**CONCLUSION**

For the foregoing reasons, appellants respectfully submit that the Examiner has erred in rejecting this application under 35 USC § 103(a). Please reverse the Examiner on all counts.

Respectfully submitted,

August 13, 2004  
Date

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3M Innovative Properties Company  
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**APPENDIX**

1. An electronic package, comprising:
  - a conductive trace layer having a first side and a second side, the conductive trace layer being patterned to define a plurality of interconnect pads;
  - a dielectric substrate mounted on the first side of the conductive trace layer;
  - an embedded capacitor having a capacitance of from about 1 nF/sq.cm. to about 100 nF/sq.cm., including a first conductive layer, a second conductive layer and a layer of dielectric material made of a non-conductive polymer blended with high dielectric constant particles disposed between the first and the second conductive layers, the first conductive layer attached to the second side of the conductive trace layer by a first adhesive layer;
  - a plurality of interconnect regions extending through the first conductive layer and the dielectric material layer of the capacitor; and
  - an interconnect member connected between each of the conductive layers of the capacitor and a corresponding set of the interconnect pads, the first conductive layer of the capacitor being electrically connected to a first set of the interconnect pads and the second conductive layer of the capacitor being electrically connected to a second set of the interconnect pads, the interconnect members corresponding to the second set of interconnect pads extending through one of the interconnect regions.

2. The electronic package of claim 1 wherein the first electrode is maintained at a first reference voltage and wherein the second electrode is maintained at a second reference voltage different from the first reference voltage.

3. The electronic package of claim 1 further comprising an electrically conductive stiffening member attached to the second conductive layer of the capacitor by a second adhesive layer.

4. The electronic package of claim 3 further comprising a device receiving region extending through the dielectric substrate, the conductive trace layer and the capacitor, and

further comprising an electronic device attached to the device receiving region on the stiffening member by a third adhesive layer.

8. The electronic package of claim 1 wherein the capacitor has a capacitance of from about 2 nF/sq. cm. to about 30 nF/sq. cm.

9. The electronic package of claim 1 wherein the capacitor has a capacitance of from about 5 nF/sq. cm. to about 15 nF/sq. cm.

10. The electronic package of claim 1 wherein the capacitor has a capacitance of at least 30nF/sq. cm.

11. The electronic package of claim 1 wherein the dielectric material of the capacitor has a thickness of from about 0.5 um to about 30 um.

12. The electronic package of claim 1 wherein the dielectric material of the capacitor includes a metal oxide.

13. The electronic package of claim 1 wherein the dielectric constant particles are formed from a material selected from the group consisting of barium titanate, barium strontium titanate, titanium oxide, lead zirconium titanate and tantalum oxide.

14. The electronic package of claim 1 wherein the dielectric substrate includes a plurality of apertures, each one of the apertures being positioned adjacent to one of the interconnect region of the capacitor.

15. The electronic package of claim 1 wherein the dielectric substrate includes a polymeric film.

16. The electronic package of claim 15 wherein said polymeric film is polyimide film.

17. The electronic package of claim 1 wherein the interconnect member is a solder plug.

18. The electronic package of claim 1 wherein each interconnect pad is a solderball pad.
19. The electronic package of claim 18 wherein the dielectric substrate has an aperture extending therethrough adjacent to each solderball pad.

**Exhibit A**

*Hawley's*

*Condensed Chemical*

*Dictionary*

**THIRTEENTH EDITION**

*Revised by*

Richard J. Lewis, Sr.



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Alabama, California, Pennsylvania, Cyprus, and Italy. Burnt sienna is an orange-brown pigment made by calcining raw sienna.  
See ochre; iron oxide reds.

**Use:** Colorant in oil paints, stains, pastels, etc.

**sieve.** See screen.

**Sievert's law.** Refers to the solubility of molecules that dissociate during solution, varies as the square root of the pressure.

**siglure.** (generic name for *sec*-butyl-6-methyl-3-cyclohexane-1-carboxylate).



**Properties:** Liquid. Bp 113–114°C (15 mm Hg). Soluble in most organic solvents; insoluble in water. Combustible.

**Use:** Insect attractant.

**sigma blade.** A rotating agitator set horizontally in a kneading bowl or chamber used for mixing doughs and heavy pastes. The blade or arm is shaped somewhat like a Greek capital sigma ( $\Sigma$ ) lying on its side; variations of this shape simulate horizontal letters S and Z. Some kneaders have two such blades that overlap as they turn to provide maximum mixing efficiency.

See kneading.

**sigma bond.** A covalent bond directed along the line joining the centers of two atoms. They are the normal single bonds in organic molecules.

See pi bond.

**sigma function.** Enthalpy of an air-stream mix, minus the heat of the liquid.

**sigma phase.** The nonmagnetic, brittle, corundum-hard FeCr constituent in stainless steel.

**sigma value.** The value of a quantum number, which quantizes the component of angular momentum, of spin about the axis of a diatomic molecule.

**sig water.** The alkaline solution of soda ash, borax, or ammonia for washing the grain surface of leather before applying color or dye.

**silane.** (silicon tetrahydride).

CAS: 7803-62-5. SiH<sub>4</sub>.

**Properties:** A gas; repulsive odor. Solidifies at –200°C, bp –112°C, d 0.68. Decomposes in water; insoluble in alcohol and benzene.

**Hazard:** Dangerous fire risk, ignites spontaneously in air. Strong irritant to tissue. TLV: 5 ppm in air.

**Use:** Doping agent for solid-state devices, production of amorphous silicon.

**silane compounds.** Gaseous or liquid compounds of silicon and hydrogen (Si<sub>n</sub>H<sub>2n+2</sub>), analo-

gous to alkanes or saturated hydrocarbons. SiH<sub>3</sub> is called silyl (analogous to methyl), and Si<sub>2</sub>H<sub>5</sub> is disilanyl (analogous to ethyl). A cyclic silicon and hydrogen compound having the formula SiH<sub>2</sub> is called a cyclosilane. Organofunctional silanes are noted for their ability to bond organic polymer systems to inorganic substrates.

**Hazard:** Dangerous fire risk.

See silicone; siloxane.

**"Silastic" [Dow Corning].** TM for compositions in physical character comparable to milled and compounded rubber prior to vulcanization but containing organosilicon polymers. Parts fabricated of "Silastic" are serviceable from –73 to +260°C, retain good physical and dielectric properties in such service, show excellent resistance to compression set, weathering, and corona. Thermal conductivity is high, water absorption low.

**Use:** Diaphragms, gaskets and seals, O-rings, hose, coated fabrics, wire and cable, and insulating components for electrical and electronic parts.

**"Silbond" [Stauffer].** TM for ethyl silicate, available as pure, condensed, prehydrolyzed, and specialty formulations.

**silica.** (silicon dioxide). SiO<sub>2</sub>. Occurs widely in nature as sand, quartz, flint, diatomite.

**Properties:** Colorless crystals or white powder; odorless and tasteless. D 2.2–2.6; thermal conductivity about half that of glass, mp 1710°C, bp 2230°C, high dielectric constant, high heat and shock resistance. Insoluble in water and acids except hydrogen fluoride; soluble in molten alkali when finely divided and amorphous. Combines chemically with most metallic oxides; melts to a glass with lowest known coefficient of expansion (fused silica). Non-combustible.

**Derivation:** Can be made from a soluble silicate (water glass) by acidification, washing and ignition. Arc silica is made from sand, vaporized in a 3000°C electric arc.

**Grade:** By purity and mesh size, silica aerogel, hydrated, precipitated.

**Hazard:** Toxic by inhalation, chronic exposure to dust may cause silicosis.

**Use:** (Powder) Manufacture of glass, water glass, ceramics, abrasives, water filtration, microspheres, component of concrete, source of ferrosilicon and elemental silicon, filler in cosmetics, pharmaceuticals, paper, insecticides, hydrated and precipitated grades as rubber reinforcing agent, including silicone rubber, anticaking agent in foods, flattening agents in paints, thermal insulator. (Fused) Ablative material in rocket engines, spacecraft, etc.; fibers in reinforced plastics; special camera lenses. (Amorphous) Silica gel.

See quartz; silicic acid; silica gel.

**silica, fumed.** A colloidal form of silica made by combustion of silicon tetrachloride in hydrogen-oxygen furnaces. Fine, white powder.

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**On the cover: Photomicrograph of crystals of vitamin B<sub>1</sub>.  
(Dennis Kunkel, University of Hawaii)**

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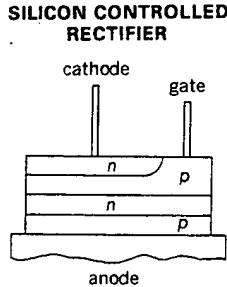
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Diagrammatic view of typical silicon controlled rectifier showing four alternate layers of p-type and n-type material.

ments, chiefly in the iron group, resulting from the photodisintegration of silicon-28 and other intermediate-mass nuclei; copious supplies of protons, alpha particles, and neutrons are produced, followed by the capture of these particles by other intermediate-mass nuclei. { 'sil-ə-kən 'bərn-ing }

**silicon capacitor** [ELECTR] A capacitor in which a pure silicon-crystal slab serves as the dielectric; when the crystal is grown to have a *p* zone, a depletion zone, and an *n* zone, the capacitance varies with the externally applied bias voltage, as in a varactor. { 'sil-ə-kən kə'pas-əd-ər }

**silicon carbide** [INORG CHEM] SiC Water-insoluble, bluish-black crystals, very hard and iridescent; soluble in fused alkalies; sublimes at 2210°C; used as an abrasive and a heat refractory, and in light-emitting diodes to produce green or yellow light. { 'sil-ə-kən 'kär,bīd }

**silicon chloride** See silicon tetrachloride. { 'sil-ə-kən 'klōr,īd }

**silicon controlled rectifier** [ELECTR] A semiconductor rectifier that can be controlled; it is a *pnpn* four-layer semiconductor device that normally acts as an open circuit, but switches rapidly to a conducting state when an appropriate gate signal is applied to the gate terminal. Abbreviated SCR. Also known as reverse-blocking triode thyristor. { 'sil-ə-kən kən'trōld 'rek-tə,fī-rər }

**silicon controlled switch** [ELECTR] A four-terminal switching device having four semiconductor layers, all of which are accessible; it can be used as a silicon controlled rectifier, gate-turnoff switch, complementary silicon controlled rectifier, or conventional silicon transistor. Abbreviated SCS. Also known as reverse-blocking tetrode thyristor. { 'sil-ə-kən kən'trōld 'swich }

**silicon copper** [MET] An alloy containing 70–80% copper and 20–30% silicon, used as an addition to molten copper or brass. { 'sil-ə-kən 'kāp-ər }

**silicon detector** See silicon diode. { 'sil-ə-kən di'tek-tər }

**silicon diode** [ELECTR] A crystal diode that uses silicon as a semiconductor; used as a detector in ultra-high- and super-high-frequency circuits. Also known as silicon detector. { 'sil-ə-kən 'dī,ōd }

**silicon dioxide** [INORG CHEM]  $\text{SiO}_2$  Colorless, transparent crystals, soluble in molten alkalies and hydrofluoric acid; melts at 1710°C; used to make glass, ceramic products, abrasives, foundry molds, and concrete. { 'sil-ə-kən dī'āk,sīd }

**silicone** [MATER] A fluid, resin, or elastomer; can be a grease, a rubber, or a foamable powder; the group name for heat-stable, water-repellent, semiorganic polymers of organic radicals attached to the silicones, for example, dimethyl silicone; used in adhesives, cosmetics, and elastomers. { 'sil-ə,kōn }

**silicon fluoride** See silicon tetrafluoride. { 'sil-ə-kən 'flür,īd }

**silicon halide** [INORG CHEM] A compound of silicon and a halogen; for example,  $\text{SiBr}_4$ ,  $\text{Si}_2\text{Br}_6$ ,  $\text{SiCl}_4$ ,  $\text{Si}_2\text{Cl}_6$ ,  $\text{Si}_3\text{Cl}_8$ ,  $\text{SiF}_4$ ,  $\text{Si}_2\text{F}_6$ ,  $\text{SiL}_4$ , and  $\text{Si}_2\text{F}_6$ . { 'sil-ə-kən 'ha,līd }

**silicon hydride** See silane. { 'sil-ə-kən 'hī,dīd }

**silicon image sensor** [ELECTR] A solid-state television camera in which the image is focused on an array of individual light-sensitive elements formed from a charge-coupled-device semiconductor chip. Also known as silicon imaging device. { 'sil-ə-kən 'im'ij,sənsər }

**silicon imaging device** See silicon image sensor. { 'sil-ə-kən 'im'ij-ing di,vīs }

**siliconized graphite** [MATER] A graphite material whose surface has been chemically converted to silicon carbide. { 'sil-ə-kə,nīz'd gra,fit }

**silicizing** [MET] Diffusing silicon into solid metal at an elevated temperature. { 'sil-ə-kə,nīz-ing }

**silicon micromachining** [DES ENGI] The use of chemical and plasma techniques to fabricate miniature mechanical devices and components from single-crystal silicon. { 'sil-ə,kān 'mī-kro'mā'shēn-ing }

**silicon monoxide** [INORG CHEM]  $\text{SiO}$  A hard, abrasive, amorphous solid used as thin surface films to protect optical parts, mirrors, and aluminum coatings. { 'sil-ə-kən mē'nāk,sīd }

**silicon nitride** [INORG CHEM]  $\text{Si}_3\text{N}_4$  A white, water-insoluble powder, resistant to thermal shock and to chemical reagents; used as a catalyst support and for stator blades of high-temperature gas turbines. { 'sil-ə-kən 'nī,trīd }

**silicon-on-insulator** [ELECTR] A semiconductor manufacturing technology in which thin films of single-crystalline silicon

are grown over an electrically insulating substrate. { 'sil-ə-kən ən 'in'sə,lād-ər }

**silicon-on-sapphire** [ELECTR] A semiconductor manufacturing technology in which metal oxide semiconductor devices are constructed in a thin single-crystal silicon film grown on an electrically insulating synthetic sapphire substrate. Abbreviated SOS. { 'sil-ə-kən ən 'sa,fīr }

**silicon pn junction detector** [NUCLEO] A type of junction detector made by diffusing an *n*-type dopant, usually phosphorus, about 2 micrometers into the surface of a *p*-type silicon substrate. { 'sil-ə-kən 'pē'en jēn'k-shən di'tek-tər }

**silicon rectifier** [ELECTR] A metallic rectifier in which rectifying action is provided by an alloy junction formed in a high-purity silicon slab. { 'sil-ə-kən 'rek-tə,fī-rər }

**silicon resistor** [ELECTR] A resistor using silicon semiconductor material as a resistance element, to obtain a positive temperature coefficient of resistance that does not appreciably change with temperature; used as a temperature-sensing element. { 'sil-ə-kən ri'zis-tər }

**silicon solar cell** [ELECTR] A solar cell consisting of *p* and *n* silicon layers placed one above the other to form a *pn* junction at which radiant energy is converted into electricity. { 'sil-ə-kən 'sō-lər 'sel }

**silicon steel** [MET] A steel that contains 0.5–4.5% silicon, used in electric transformer coils. { 'sil-ə-kən 'stēl }

**silicon surface barrier detector** [NUCLEO] A type of junction detector made from a wafer of *n*-type silicon which is subjected to etching and surface treatments to create a thin layer of *p*-type material and then receives a thin layer of gold evaporated onto the surface. { 'sil-ə-kən 'sərfəs 'bar-ē-ər di,tek-tər }

**silicon-symmetrical switch** [ELECTR] Thyristor modified by adding a semiconductor layer so that the device becomes a bidirectional switch; used as an alternating-current phase control, for synchronous switching and motor speed control. { 'sil-ə-kən si'me-trē-kəl 'swich }

**silicon tetrabromide** [INORG CHEM]  $\text{SiBr}_4$  A fuming, colorless liquid that yellows in air; disagreeable aroma; boils at 153°C. Also known as silicon bromide. { 'sil-ə-kən 'te-trō'bromid }

**silicon tetrachloride** [INORG CHEM]  $\text{SiCl}_4$  A clear, corrosive, fuming liquid with suffocating aroma; decomposes in water and alcohol; boils at 57.6°C; used in warfare smoke screens, to make ethyl silicate and silicones, and as a source of pure silicon and silica. Also known as silicon chloride. { 'sil-ə-kən 'te-trō'klōr,īd }

**silicon tetrafluoride** [INORG CHEM]  $\text{SiF}_4$  A colorless, suffocating gas absorbed readily by water, in which it decomposes; boiling point, -86°C; used in chemical analysis and to make fluosilicic acid. Also known as silicon fluoride. { 'sil-ə-kən 'te-trō'flür,īd }

**silicon transistor** [ELECTR] A transistor in which silicon is used as the semiconducting material. { 'sil-ə-kən tran'sistor }

**silicosiderosis** [MED] Pneumoconiosis caused by inhalation of silicate- and iron-containing dust. { 'sil-ə-kō,sid'ə-rōsəs }

**silicosis** [MED] Pneumoconiosis due to the inhalation of silica ( $\text{SiO}_2$ ) particles. { 'sil-ə,kōsəs }

**silicospiegel** [MET] A spiegeleisen pig iron containing 15–20% manganese and 8–15% silicon and up to 4% carbon with the balance iron; used in making steel. { 'sil-ə-kō'spēgəl }

**silicothemic process** See Pidgeon process. { 'sil-ə-kō'thēmik 'prāsəs }

**silification** See silicification. { 'sil-ə-fē'kā-shən }

**sillque** [BOT] A silex-like capsule, but usually at least four times as long as it is wide, which opens by sutures at either margin and has parietal placentation. { 'sil'ēk }

**silk** [GEOL] Microscopic needle-shaped crystalline inclusions of rutile in a natural gem from which subsurface reflections produce a whitish sheen resembling that of a silk fabric. [INV ZOO] A continuous protein fiber consisting principally of fibroin and secreted by various insects and arachnids, especially the silkworm, for use in spinning cocoons, webs, egg cases, and other structures. [TEXT] A thread or fabric made from silk secretions of the silkworm. { 'silk' }

**silk cotton** See kapok. { 'silk'käp-ək }

**silk cotton tree** See kapok tree. { 'silk'kät'ən,trē }

**silk gland** [INV ZOO] A gland in certain insects which secretes a viscous fluid in the form of filaments known as silk; it is a

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